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Peterson,
J. T.

CapPost- Capture and Posterior Probability of Presence Estimation

Users Guide Version 1.0

CapPost- Capture and posterior probability of presence estimation

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James T. Peterson and Jianping Zhu
USGS, Georgia Cooperative Fish and Wildlife Research Unit, Warnell School of Forest Resources, Athens, GA 30602

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1.0 INTRODUCTION

CapPost is stand-alone software for estimating stream-dwelling salmonid capture probabilities for three sampling methods: single-pass day snorkeling and night snorkeling and 1 - 3 pass backpack electrofishing. Theses estimates then are used to estimate detection probabilities, sample size requirements for detection, and posterior presence probabilities. CapPost also allows users to specify capture probabilities. In the following sections, we provide a brief description and example of each estimation technique. These descriptions are intended to familiarize the user with the techniques and the CapPost interface. Details regarding the capture probability models and other statistical details are provided in *Technical Stuff*. We also encourage users to consult the references cited in the manual before using the software for a more through understanding of the uses and limitations of each technique.

2.0 GETTING STARTED

2.1 Entering data

CapPost requires specific data to estimate capture probabilities, detection probabilities, etc. For example, CapPost requires sample site estimates of wetted stream cross-sectional area, specific conductance, and the amount of undercut banks to estimate bull trout electrofishing capture probabilities. For many techniques, users will be prompted to enter the data in pop-up menus, whereas other data are read directly from the CapPost spreadsheet. Entering data in the spreadsheet is similar to most spreadsheet software, such as Excel and Quatro pro. However, CapPost ***requires*** the first row in the spreadsheet to contain the column heading and ***does not*** allow missing values. For example, Figure 2.1 contains four variables: *Sample ID*, *Cross sect*, *Conduct*, and *Undercut*, representing the sample unit ID, wetted stream cross-sectional area, specific conductance, and the amount of undercut banks, respectively. Although the column headings can be up to 30 characters long, we strongly recommend the use of smaller headings for more concise outputs.

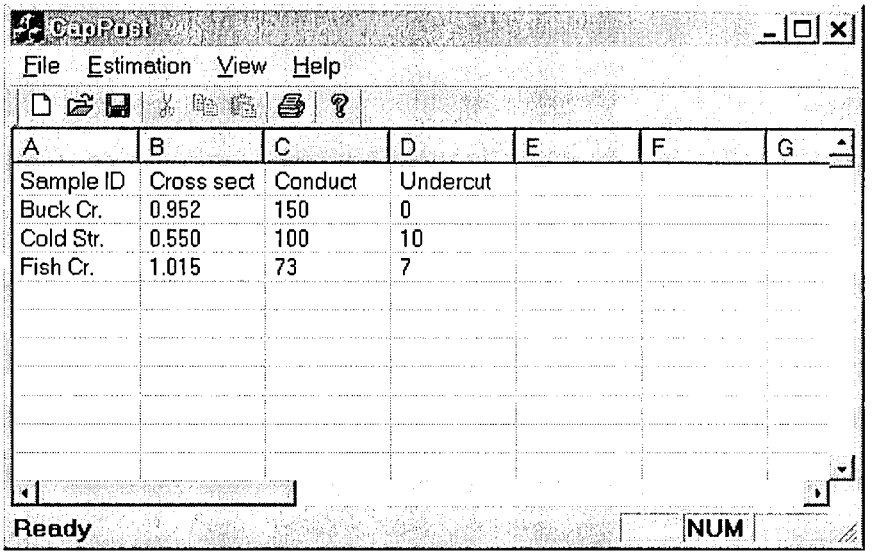


Figure 2.1. An example of a CapPost spreadsheet with four variables for three sample units.

2.2 Reading in existing data

To open existing files in CapPost, click on *File* and select *Open* (Figure 2.2). CapPost reads comma-separated text files, also known as comma delimited text files or comma-separated values. The first line of the data, however, must contain the column headings (e.g., *see* Figure 2.3). Comma-separated text files can be exported using most spreadsheet and database programs and then imported into CapPost.

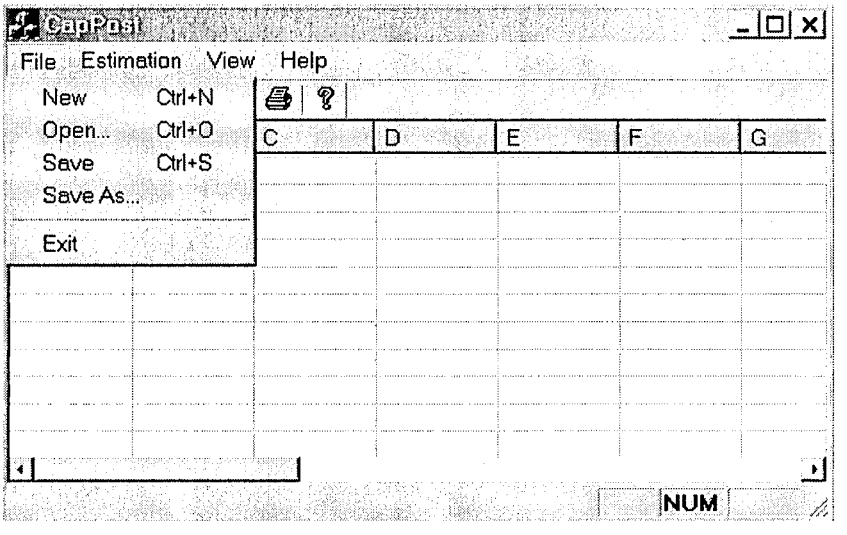


Figure 2.2. Contents of the CapPost pull down *File* menu that is used to open and save data files.

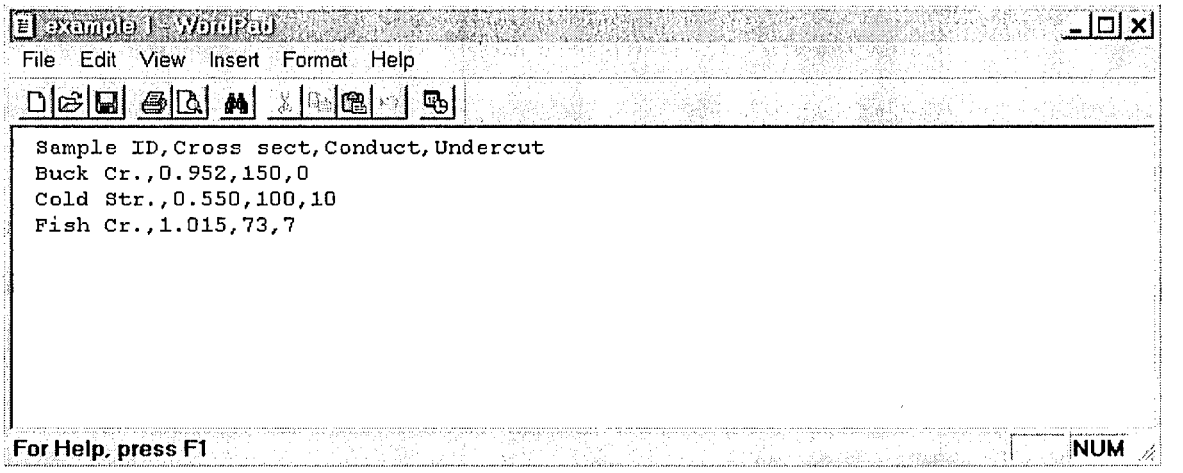


Figure 2.3. An example of a comma-separated text file (opened in WordPad) that corresponds to the data in Figure 2.1.

2.3 Saving data and model output

To save data files in CapPost, click on *File* and select *Save* or *Save as* (Figure 2.2). In contrast, users name output files in each estimation module. CapPost data files are saved in comma-separated text format and output files in regular text format. Users can specify the filename and any extension (e.g., ".txt", ".csv") for data and output files, but we recommend using ".csv" for the data files to facilitate importation into other software.

3. ESTIMATION

CapPost includes four estimation modules: capture efficiency, detection probability, sample size requirements, and posterior presence probability, which are accessed by clicking on *Estimation* and selecting the desired module (Figure 3.1). Each module has specific data requirements (Table 3.1) that should be reviewed prior to using CapPost. Below, we outline each estimation module and the corresponding variable specification menus using the 2 example data files (*example 1.csv* and *example 2.csv*) included with CapPost.

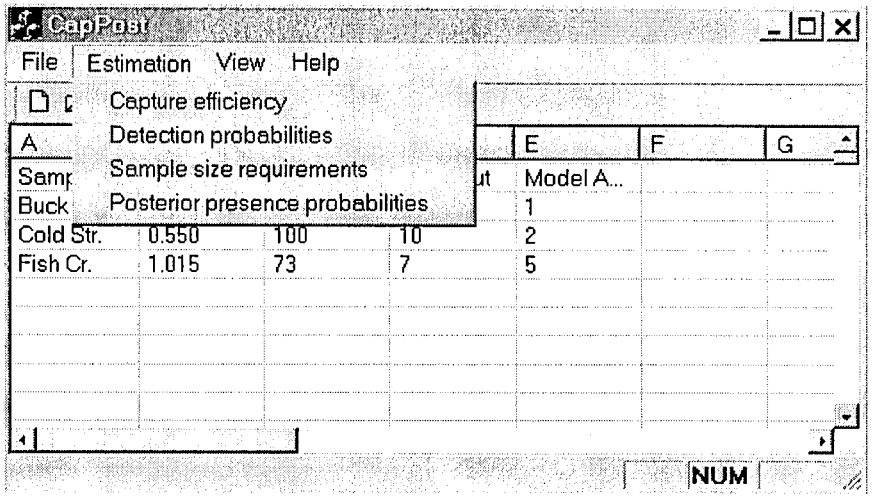


Figure 3.1. The contents of the CapPost pull down *Estimation* menu.

3.1 Capture efficiency and abundance estimates

Capture efficiency is defined as "the proportion (or percentage) of fish, in a given area, that are captured during sampling" following Peterson et al. (2004). CapPost estimates capture efficiency for bull trout and *Oncorhynchus sp.* (i.e., combined rainbow trout and cutthroat trout) using the method- specific models described in Section 4.1. To estimate capture efficiency, click on *Estimation* and select *Capture efficiency* (Figure 3.1). The species and sampling method are specified by highlighting the corresponding circles (Figure 3.2). Users then are prompted to select the columns corresponding to the variables required to estimate capture efficiency (e.g., site specific habitat characteristics) and the name of the output file (Figure 3.3). Capture efficiencies are estimated by clicking *Calculate*. CapPost then calculates capture efficiency and outputs total length-group specific estimates for each sample unit (Figure 3.4). Note that CapPost includes a warning in the output if variables (e.g., site specific habitat characteristics) for a given sample unit are outside of the range of those encountered during gear calibration and should be considered suspect (see Appendix 6.1).

Table 3.1. Required input variables for each CapPost estimation module, by method and species.

Estimation module	Required input variables
Capture efficiency	
Bull trout	
Single-pass day snorkeling	Mean water temperature, percent rubble substrate, underwater visibility, wood density
Single-pass night snorkeling	Mean water temperature, percent pool habitat
1-3 pass electrofishing	Mean wetted stream cross-sectional area, specific conductance, percent undercut banks
Oncorhynchus	
Single-pass day snorkeling	Mean wetted stream cross-sectional area
Single-pass night snorkeling	Percent rubble substrate, percent pool habitat
1 pass electrofishing	Mean wetted stream cross-sectional area
2 pass electrofishing	Mean water temperature, percent cobble substrate
3 pass electrofishing	Mean water temperature, percent cobble substrate, percent pool habitat
Detection probability	Capture efficiency, mean and variance of fish abundance per sample unit
Bull trout	Method specific variables for estimating capture efficiency, detailed above
Oncorhynchus	Method specific variables for estimating capture efficiency, detailed above
User-supplied efficiency	Estimated capture efficiency and dispersion (variance), if available
Sample size requirements	Capture efficiency, mean and variance of threshold fish abundance per sample
Bull trout	Method specific variables for estimating capture efficiency, detailed above
Oncorhynchus	Method specific variables for estimating capture efficiency, detailed above
User-supplied efficiency	Estimated capture efficiency and dispersion (variance), if available
Posterior presence probabilities	
Sample unit	Sample unit-specific capture efficiency and estimated abundance, negative binomial dispersion parameter if available
Patch/Watershed	Patch prior probability of presence, sample unit-specific capture efficiency, threshold fish abundance per sample unit and variance
Bull trout	Method specific variables for estimating capture efficiency, detailed above
Oncorhynchus	Method specific variables for estimating capture efficiency, detailed above
User supplied efficiency	Estimated capture efficiency and dispersion (variance) if available

Fish abundance can be estimated using the size group-specific capture probabilities and the number of fish captured (or counted during snorkeling) as n/p, where n is the number of fish captured (or counted) and p is the estimated capture efficiency (Peterson et al. 2004). For example, assume that 10 fish with total length between 60-99 mm and 5 fish with total length between 200-350 mm were captured in Buck Cr. (Figure 3.4). The estimated number of fish 60-99 mm is 10/0.3134 = 32 and 200-350 mm fish is 5/0.6359 = 8.

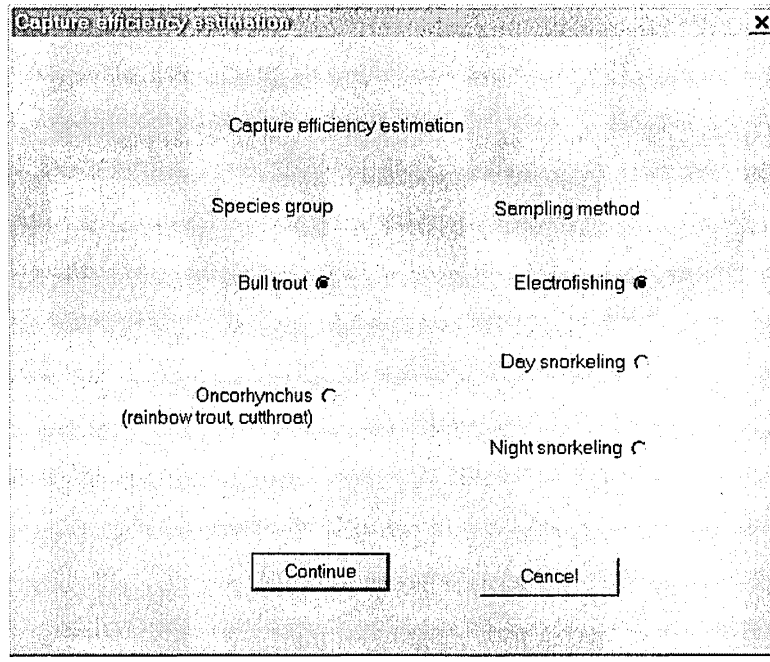


Figure 3.2. CapPost sampling method and species specification menu for capture efficiency estimation. Note that capture efficiency for rainbow trout and cutthroat trout are estimated when *Oncorhynchus* is selected.

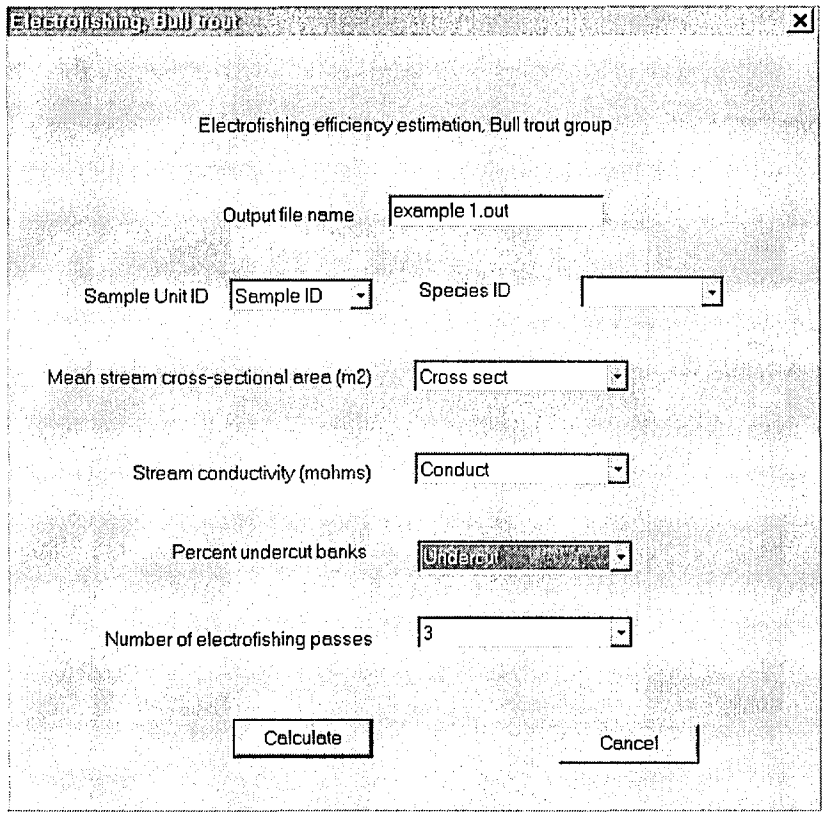


Figure 3.3. An example of variable specification for bull trout 3-pass electrofishing capture efficiency estimation using data in *example 1.csv*. Note that the sample unit ID and species ID variables are optional.

example 1 - Notepad

File Edit Format View Help

```
Electrofishing capture efficiency estimation using models from Thurow et al. 2003
Species group: Bull trout
Number of Electrofishing passes: 3

                    Estimation efficiency, by size group
        Sample ID          60-99mm          100-199m          200-350m
         Buck Cr.           0.3134            0.5229            0.6359
        Cold Str.           0.3213            0.5321            0.6444
         Fish Cr.           0.2243            0.4098            0.5253
```

Figure 3.4. An example of CapPost capture efficiency estimate output for bull trout 3-pass electrofishing using data in *example 1.csv*.

3.2 Estimating detection probabilities

CapPost estimates detection probabilities following Peterson et al. (2002) and Bonar et al. (2000), detailed in Section 4.2. These techniques require estimates of capture efficiency and (threshold) fish abundance. CapPost estimates capture efficiency for two body length ranges of bull trout and *Oncorhynchus sp.* (i.e., combined rainbow trout and cutthroat trout) using models similar to those described above (Section 4.1). These body length ranges were selected to represent juvenile salmonids (< 200 mm) and juvenile and adult size (< 350 mm) ranges. Users also have the option of supplying estimates of capture efficiency.

To estimate detection probabilities, click on *Estimation* and select *Detection probabilities* (Figure 3.1). The species and sampling method or user-supplied efficiency are specified by highlighting the corresponding circles or checking the appropriate box, respectively (Figures 3.5 and 3.6, top). Users then are prompted to select the columns corresponding to the variables required to estimate capture efficiency (Figure 3.5, bottom) or the column corresponding to the user-supplied efficiency (Figure 3.6, bottom) and to name the output file. Users also are required to enter the threshold mean abundance per sample unit and among sample unit coefficient of variation (CV) expressed as a percentage (standard deviation divided by the mean times 100, *see* Section 4.2). When using the user-supplied efficiency, a beta-binomial dispersion parameter can be specified to account for extra variation in the capture efficiency estimate (see section 4.2). The abundance, CV, and dispersion parameter values can be based on previous sampling data (e.g., Peterson et al. 2002) or expert opinion (e.g., Bonar et al. 2000). Detection probabilities are estimated by clicking *Calculate*. CapPost then calculates detection probabilities and outputs estimates for each sample unit and body length range group (Figure 3.7, top). These values represent size and sample unit-specific detection probabilities. Calculation of the total probability of detection, across sample units, can be specified in the first menu and is printed at the bottom of the output file (Figure 3.7). Similar to the capture efficiency estimates, the CapPost output file includes a warning if variables (e.g., site specific habitat characteristics) for a given sample unit are outside of the range of those encountered during gear calibration. These estimates should be considered suspect.

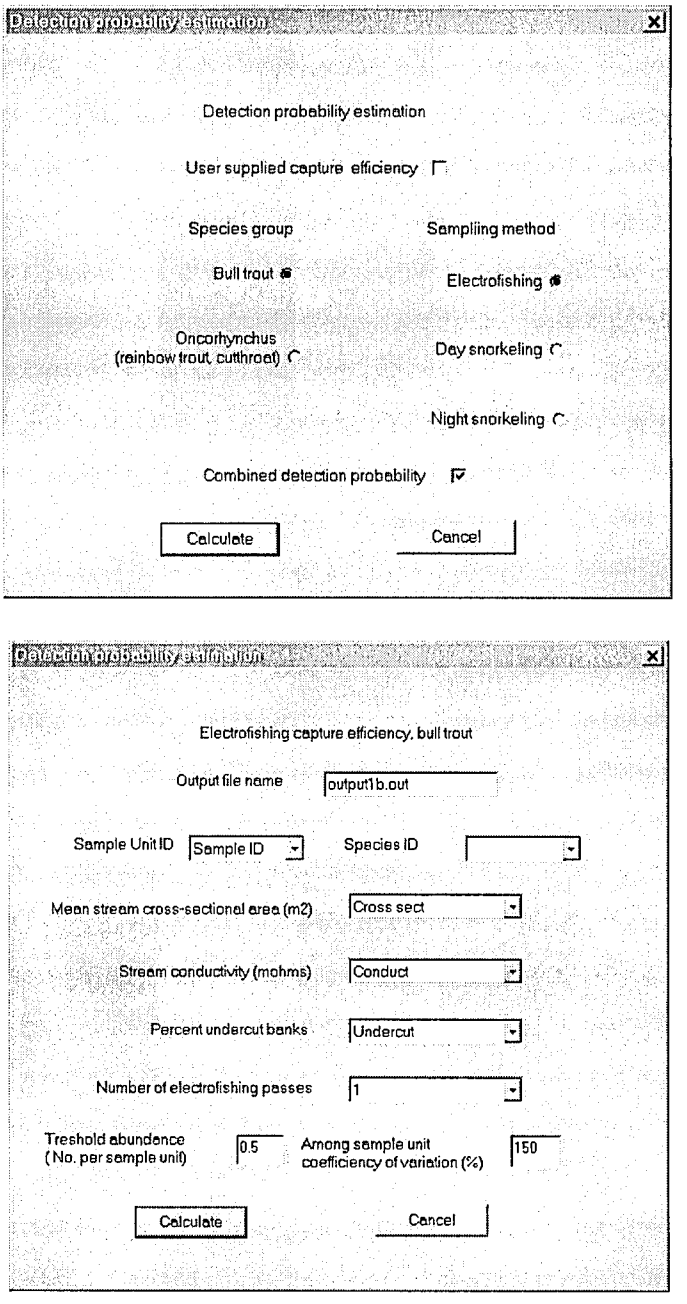


Figure 3.5. CapPost species and sampling method specification menu (top) and variable specification menu (bottom) for bull trout detection probability estimates. Here, specifications include: stream habitat characteristics in *example 1.csv*, a threshold abundance of 0.5, coefficient of variation of 150%, and 1-pass electrofishing. The corresponding output is in Figure 3.7, top.

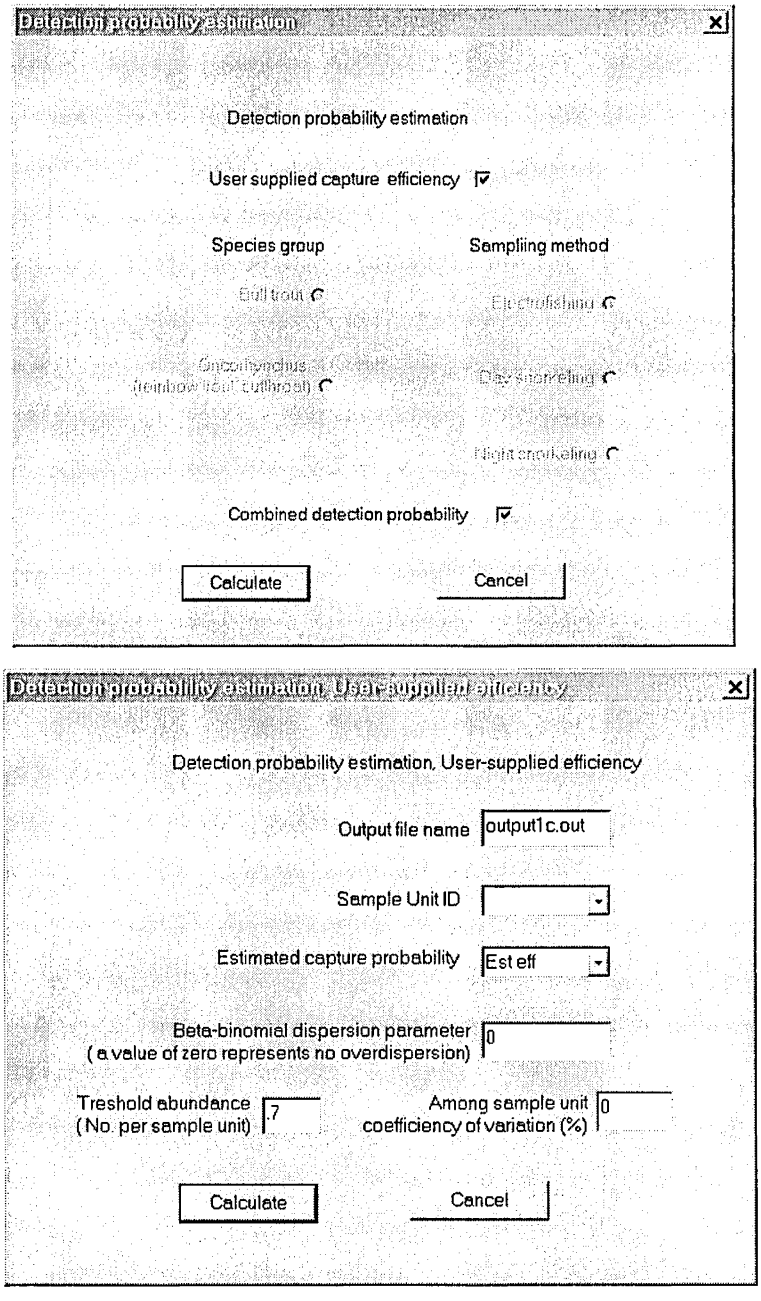
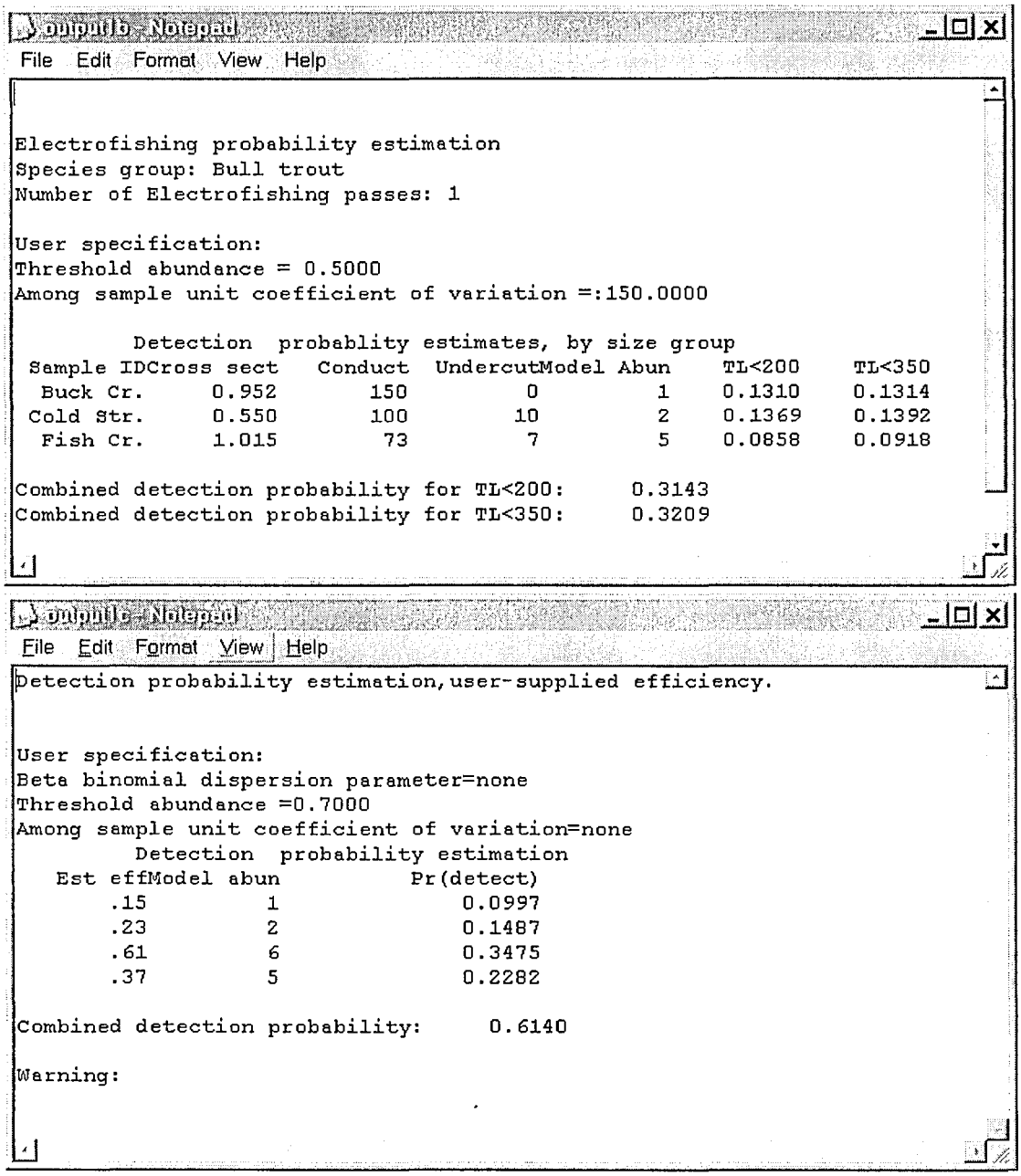


Figure 3.6. CapPost species and sampling method specification menu with user-supplied efficiency selected for estimating detection probabilities (top) and variable specification menu (bottom). Here, variable specification includes: estimated efficiency in *example 2.csv* (no overdispersion), a threshold abundance of 0.7, and a random fish distribution (coefficient of variation $\leq$ 100). Corresponding output is in Figure 3.7, bottom.



output1a - Notepad

File Edit Format View Help

```
Electrofishing probability estimation
Species group: Bull trout
Number of Electrofishing passes: 1

User specification:
Threshold abundance = 0.5000
Among sample unit coefficient of variation =:150.0000

         Detection  probablity estimates, by size group
 Sample IDCross sect   Conduct  UndercutModel Abun     TL<200     TL<350
  Buck Cr.      0.952       150          0          1    0.1310     0.1314
 Cold Str.      0.550       100         10          2    0.1369     0.1392
  Fish Cr.      1.015        73          7          5    0.0858     0.0918

Combined detection probability for TL<200:      0.3143
Combined detection probability for TL<350:      0.3209
```

output1b - Notepad

File Edit Format View Help

```
Detection probability estimation,user-supplied efficiency.


User specification:
Beta binomial dispersion parameter=none
Threshold abundance =0.7000
Among sample unit coefficient of variation=none
         Detection  probability estimation
   Est effModel abun          Pr(detect)
       .15         1              0.0997
       .23         2              0.1487
       .61         6              0.3475
       .37         5              0.2282

Combined detection probability:      0.6140

Warning:
```

Figure 3.7. An example of CapPost detection probability estimate output for bull trout 1-pass electrofishing using data in *example 1.csv* (top) and user-supplied efficiency data in *example 2.csv* (bottom). The corresponding example CapPost variable specification menus can be found in Figures 3.5 and 3.6, respectively.

3.3 Estimating sample sizes

CapPost estimates sample size requirements for detecting a species with a user-specified power level following Green and Young (1993), Peterson et al. (2002), and detailed in Section 4.3. Sample sizes estimation requires estimates of capture efficiency and (threshold) abundance and variance, and the desired probability of detection (i.e., power). CapPost also provides sample size estimates when a prior probability of presence of specified to allow users to develop optimal sampling designs (Peterson and Dunham 2003). Similar to the detection probability module, CapPost estimates capture efficiency for two body length ranges of bull trout and *Oncorhynchus sp.* (i.e., combined rainbow trout and cutthroat trout). Users also have the option of supplying estimates of capture efficiency.

To estimate required sample sizes, click on *Estimation* and select *Sample size requirements* (Figure 3.1). The species and sampling method or user-supplied efficiency are specified by highlighting the corresponding circles or checking the appropriate box, respectively (Figures 3.8 and 3.9, top). Users then are prompted to enter values for the variables required to estimate capture efficiency (Figure 3.8, bottom). The values should correspond to the average conditions that are expected during sampling based on previous surveys or expert knowledge (*see* Peterson et al. 2002). For example, Figure 3.8 (bottom) indicates that sample units will, on average, contain 10% pools and substrate will be composed of 25% rubble. Alternatively, users can provide an estimate of the average expected capture efficiency during sampling and dispersion, if necessary (Figure 3.9). Users also are required to enter the threshold mean abundance per sample unit, the among sample unit coefficient of variation (CV) expressed as a percentage (standard deviation divided by the mean times 100, *see* Section 4.2), and the desired probability of detection (power). When using the prior probabilities of presence, users must supply a desired posterior probability of presence rather than a detection probability (Figure 3.11). Sample sizes are estimated by clicking *Calculate*. CapPost then calculates sample sizes and outputs total size range-estimates (Figures 3.10 and 3.11, bottom). These values represent the approximate number of samples required for detection with the desired level of power (Figure 3.10) or to achieve the desired posterior probability of presence if undetected (Figure 3.11).

Because habitat characteristics in the sampling units will vary from unit to unit, single sample unit probabilities based habitat characteristics measured during the survey are used

for the final calculation of detection probabilities. This is easily accomplished using the sample unit-specific capture probabilities and by choosing the *Combined detection probability* option in the detection probability module. Alternatively, users can calculate sample-unit specific or patch/watershed posterior probabilities of presence (see Section 3.4).

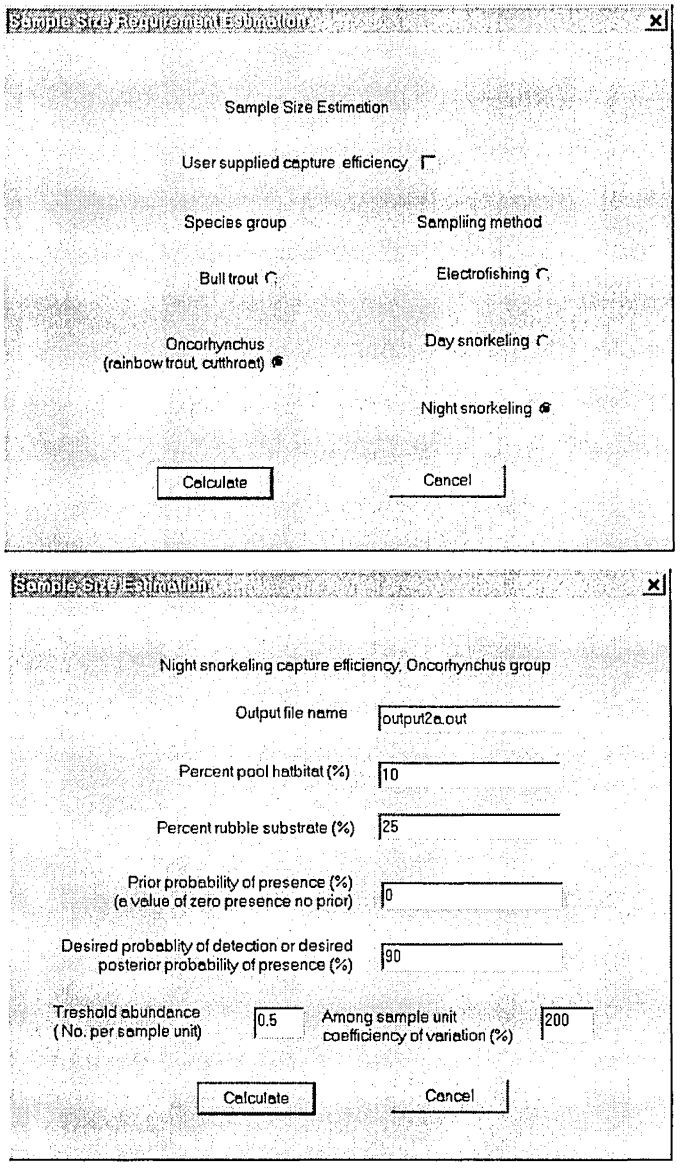


Figure 3.8. CapPost species and sampling method specification menu (top) and variable specification menu (bottom) for Oncorhynchus night snorkeling sample size requirements estimates. Here, specifications include: stream habitat characteristics, a threshold abundance of 0.5, coefficient of variation of 200%, and a desired 90% detection probability. The corresponding output is in Figure 3.10, top. Note that no prior probability of presence is specified.

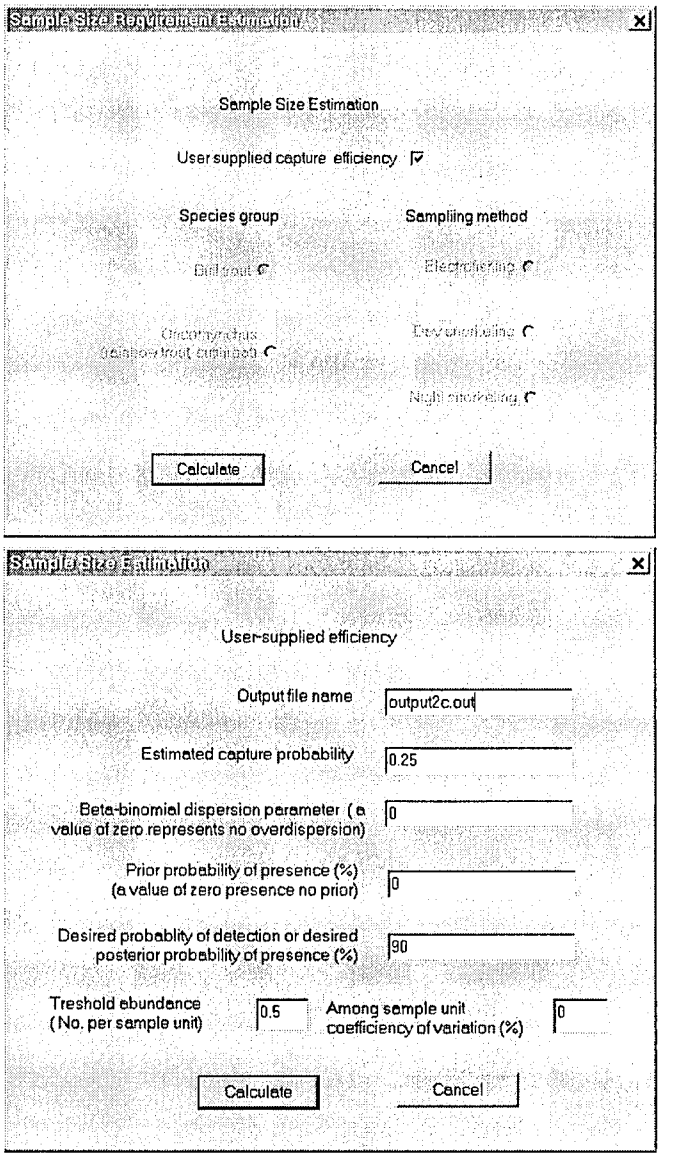


Figure 3.9. CapPost species and sampling method specification menu with user-supplied efficiency selected for estimating sample size requirements (top) and variable specification menu (bottom). Here, variable specification includes: a 25% average efficiency (no overdispersion), a threshold abundance of 0.5, and a random fish distribution (coefficient of variation < 100). Corresponding output is in Figure 3.10, bottom. Note that no prior probability of presence is specified.

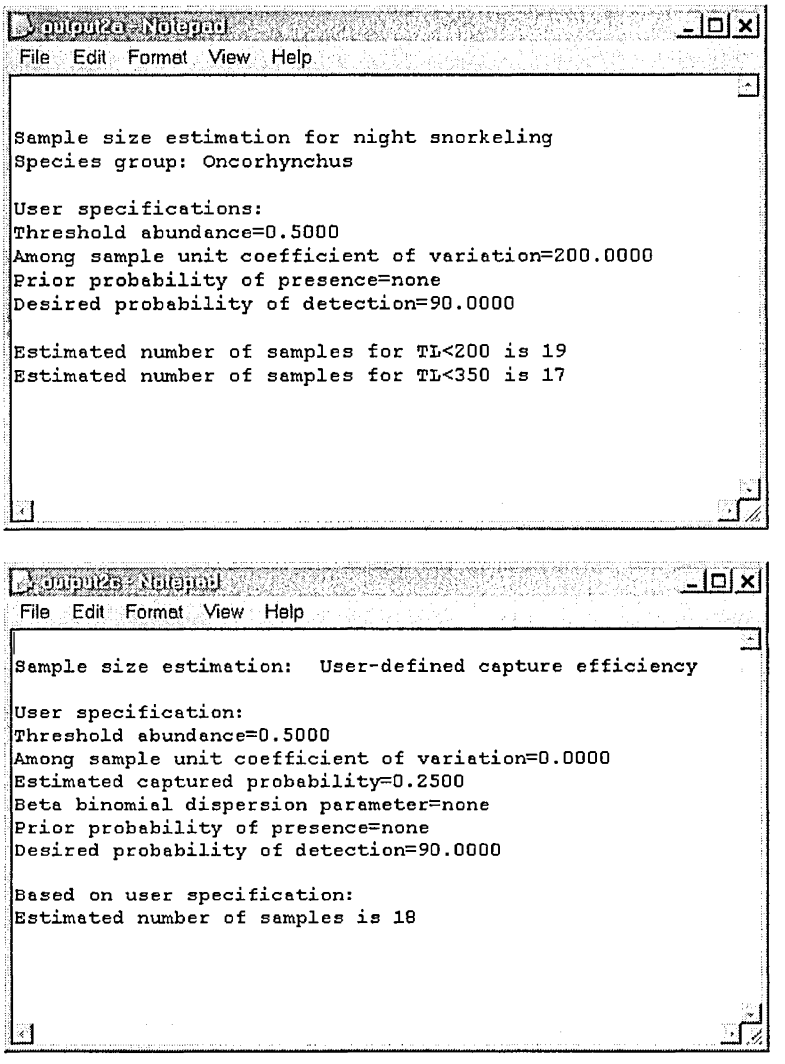

output2a - Notepad
File Edit Format View Help
Sample size estimation for night snorkeling
Species group: Oncorhynchus
User specifications:
Threshold abundance=0.5000
Among sample unit coefficient of variation=200.0000
Prior probability of presence=none
Desired probability of detection=90.0000
Estimated number of samples for TL<200 is 19
Estimated number of samples for TL<350 is 17
output2a - Notepad
File Edit Format View Help
Sample size estimation: User-defined capture efficiency
User specification:
Threshold abundance=0.5000
Among sample unit coefficient of variation=0.0000
Estimated captured probability=0.2500
Beta binomial dispersion parameter=none
Prior probability of presence=none
Desired probability of detection=90.0000
Based on user specification:
Estimated number of samples is 18

Figure 3.10. An example of CapPost sample size estimate output for Oncorhynchus night snorkeling (top) and user-supplied efficiency (bottom). The corresponding example CapPost variable specification menus can be found in Figures 3.8 and 3.9, respectively.

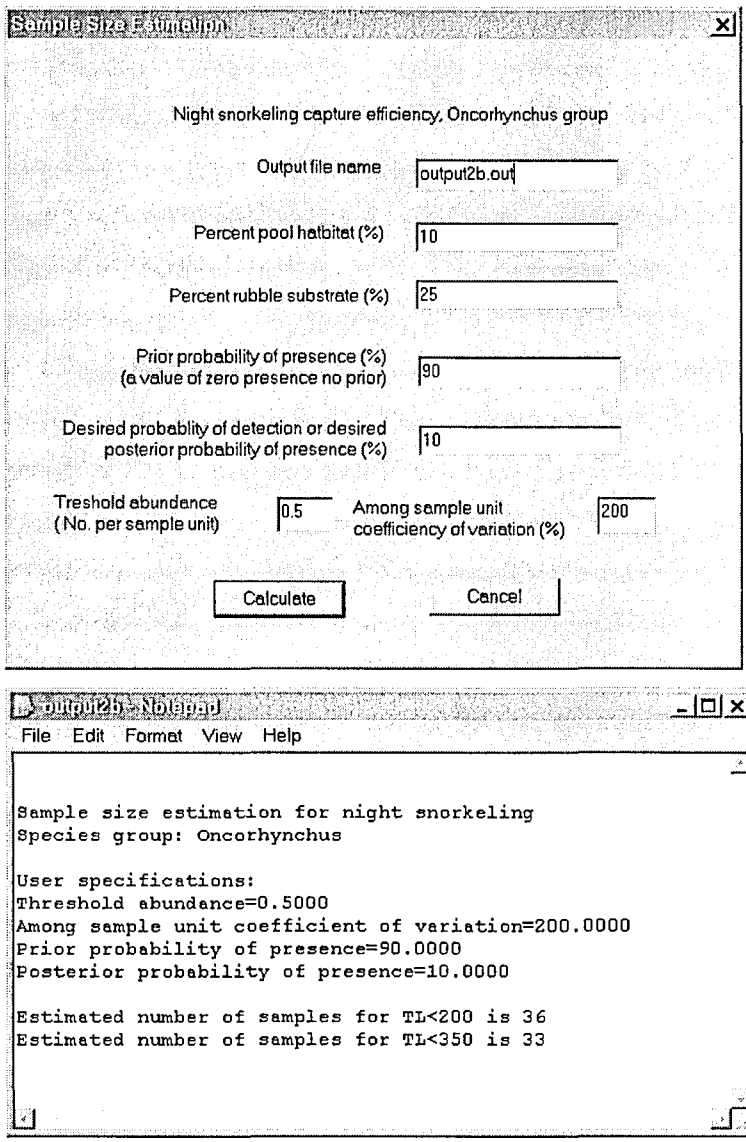


Figure 3.11. CapPost variable specification menu for Oncorhynchus night snorkeling sample size requirement estimates (top) and corresponding output (bottom). Here, specifications include: stream habitat characteristics, a threshold abundance of 0.5, coefficient of variation of 200%, a 90% prior probability of presence and a desired 10% posterior probability of presence. Notice the much larger sample sizes for the high 90% prior probability of presence compared to identical sampling conditions and no prior probability in Figure 3.10, top. The required sample sizes would be lower for a low prior probability of presence.

3.4 Posterior presence probabilities

CapPost estimates posterior probability of species presence, given that a species was not collected during sampling at two different scales, sample unit-level following Bayley and Peterson (2001) and patch/watershed-level following Peterson and Dunham (2003) and detailed in Section 4.4. Posterior presence probability estimates require capture efficiency estimates, empirical estimates of abundance and variance, and for the patch-level posterior probability, a prior probability of patch presence (i.e., occupancy, Peterson and Dunham 2003). Similar to the detection probability module, CapPost estimates capture efficiency for two body length ranges of bull trout and *Oncorhynchus sp.* (i.e., combined rainbow trout and cutthroat trout). Users also have the option of supplying estimates of capture efficiency and a dispersion parameter, if necessary.

To estimate posterior presence probabilities, click on *Estimation* and select *Posterior presence probabilities* (Figure 3.1). The species and sampling method, or user-supplied efficiency, and scale (sample unit or patch) are specified by highlighting the corresponding circles or checking the appropriate box (Figures 3.12 - 3.16, top). Users then are prompted to select the columns corresponding to the variables required to estimate capture efficiency (Figures 3.12 and 3.15, bottom) or the column corresponding to the user-supplied efficiency (Figures 3.13 and 3.16, bottom) and to name the output file. For the sample unit-scale estimates, users also are required to select the columns corresponding to the sample-unit specific empirical fish abundance estimates and enter the empirical negative binomial dispersion parameter, if necessary (Figures 3.12 and 3.13, bottom). The abundance and dispersion estimates should be based on empirical models (see Bayley and Peterson 2001). For the patch-scale estimates, users are required to enter the prior probability of patch presence, and ***conditional*** mean abundance and among sample unit coefficient of variation, expressed as a percentage (Figures 3.15 and 3.16, bottom). The conditional mean abundance and variance estimates should be based on abundance data collected from within known occupied patches (Peterson and Dunham 2003). Posterior presence probabilities are estimated by clicking *Calculation*. CapPost output for the sample-unit scale consists of the sample unit characteristics and unit-specific posterior presence probabilities, given no detection (Figure 3.14). These values represent the probability that the species occurs in the sample unit, given that it was not detected during sampling. The CapPost output for the patch

scale consists of sample-unit specific detection probabilities, based on the conditional mean abundance and capture probabilities, and the posterior probability of patch occupancy, given no detection (Figure 3.17).

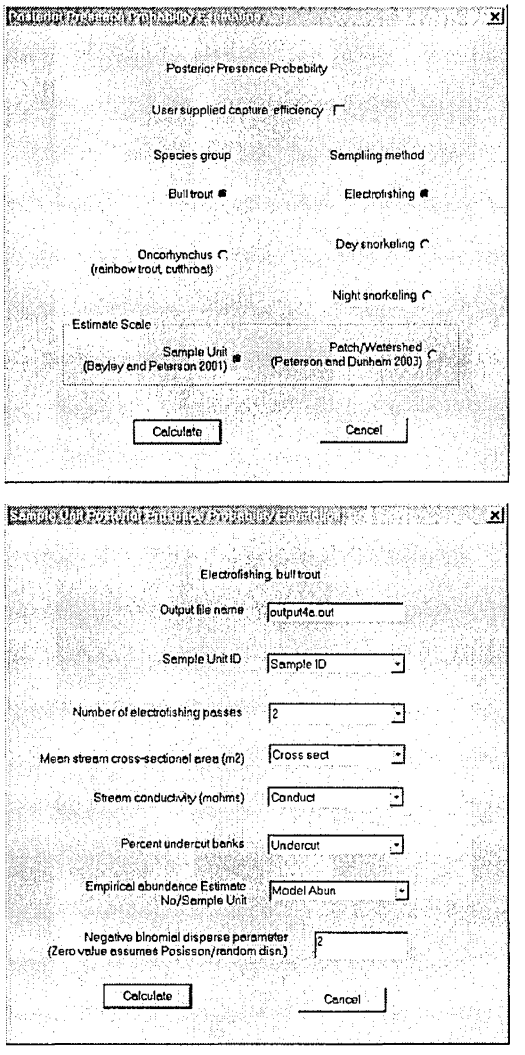


Figure 3.12. CapPost species and sampling method specification menu (top) and variable specification menu (bottom) for sample unit posterior presence estimation for bull trout. Here, specifications include: stream habitat characteristics and abundance estimates in *example 1.csv*, a negative binomial dispersion parameter of 2, and 2-pass electrofishing. The corresponding output is in Figure 3.14, top.

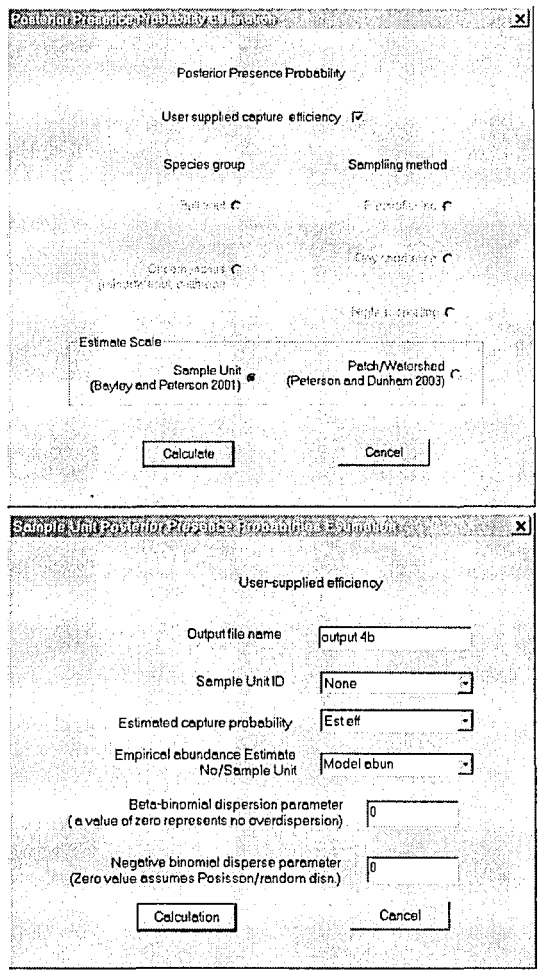


Figure 3.13. CapPost species and sampling method specification menu with user-supplied efficiency selected for estimating detection probabilities (top) and variable specification menu (bottom). Here, variable specification includes: estimated efficiency and abundance in *example 2.csv* (no overdispersion) and a random fish distribution (coefficient of variation $\leq$ 100). Corresponding output is in Figure 3.14, bottom.

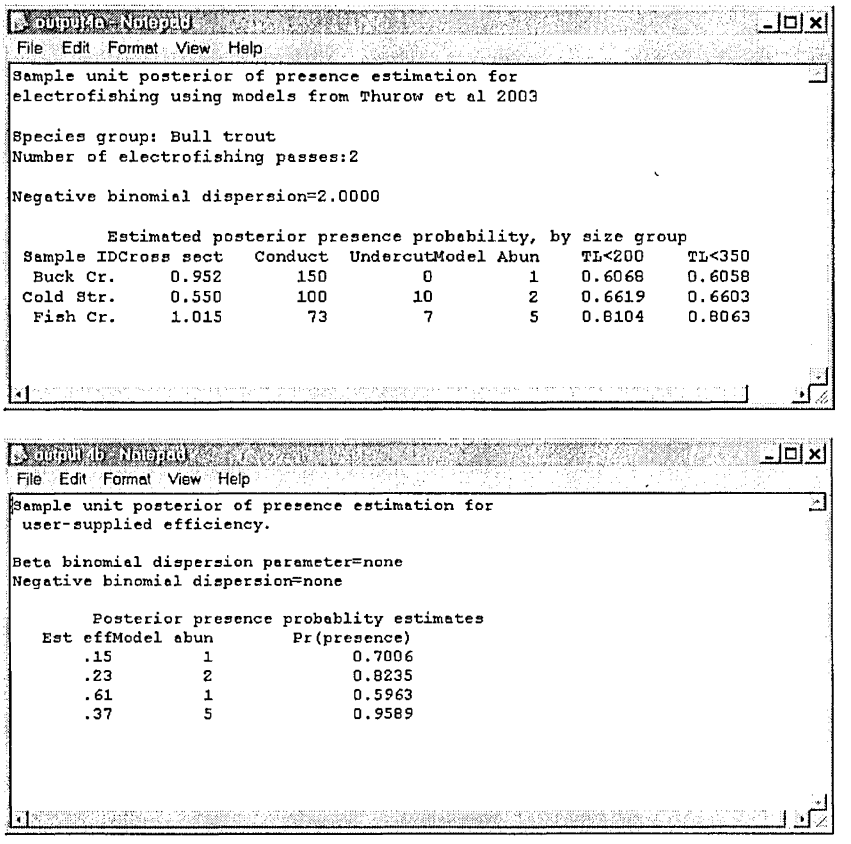

output.lb - Notepad
File Edit Format View Help
Sample unit posterior of presence estimation for
electrofishing using models from Thurow et al 2003
Species group: Bull trout
Number of electrofishing passes:2
Negative binomial dispersion=2.0000
Estimated posterior presence probability, by size group
Sample ID Cross sect Conduct UndercutModel Abun TL<200 TL<350
Buck Cr. 0.952 150 0 1 0.6068 0.6058
Cold Str. 0.550 100 10 2 0.6619 0.6603
Fish Cr. 1.015 73 7 5 0.8104 0.8063
output.lb - Notepad
File Edit Format View Help
Sample unit posterior of presence estimation for
user-supplied efficiency.
Beta binomial dispersion parameter=none
Negative binomial dispersion=none
Posterior presence probablity estimates
Est eff Model abun Pr(presence)
.15 1 0.7006
.23 2 0.8235
.61 1 0.5963
.37 5 0.9589

Figure 3.14. An example of CapPost sample unit posterior presence probability estimate for bull trout 2-pass electrofishing using data in *example 1.csv* (top) and user-supplied efficiency data in *example 2.csv* (bottom). The corresponding example CapPost variable specification menus can be found in Figures 3.12 and 3.13, respectively.

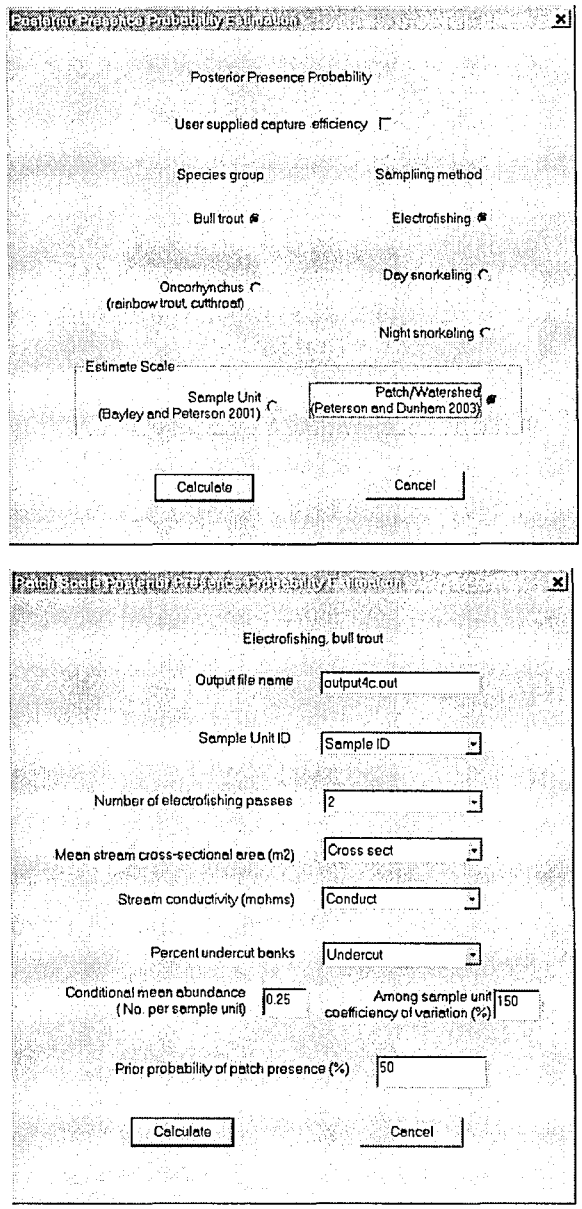


Figure 3.15. CapPost species and sampling method specification menu (top) and variable specification menu (bottom) for patch-level posterior presence probability estimates for bull trout. Here, specifications include: stream habitat characteristics in *example 1.csv*, a conditional mean abundance of 0.25, coefficient of variation of 150%, a 50% prior probability of patch occupancy, and 2-pass electrofishing. The corresponding output is in Figure 3.17, top.

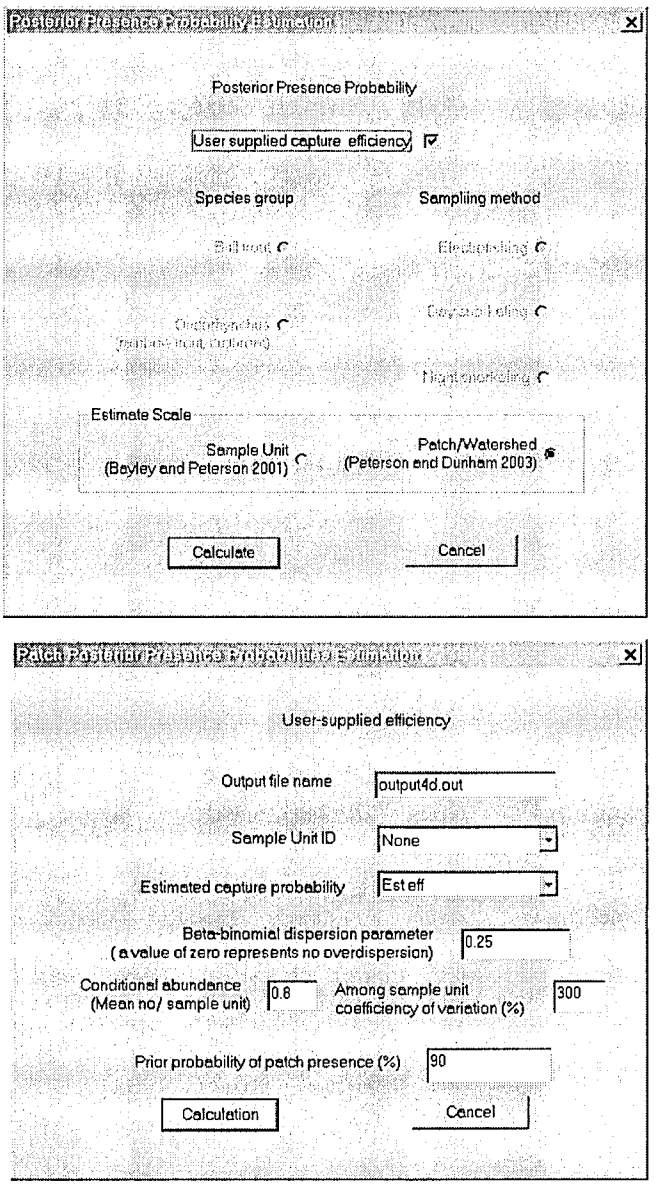
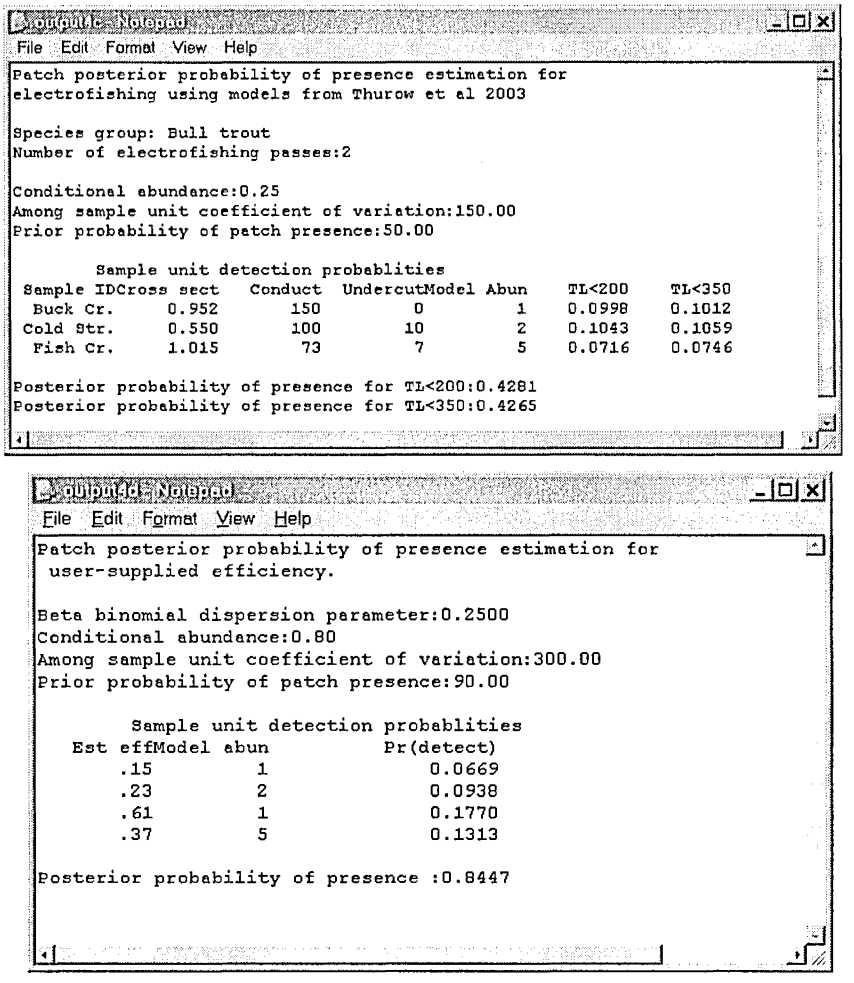


Figure 3.16. CapPost species and sampling method specification menu with user-supplied efficiency selected for patch-level posterior presence probabilities (top) and variable specification menu (bottom). Here, variable specification includes: estimated efficiency in *example 2.csv*, a beta-binomial dispersion of 0.25, a conditional mean abundance of 0.8, a coefficient of variation of 300%, and a 90% prior probability of presence. Corresponding output is in Figure 3.17, bottom.



```
output - Notepad
File  Edit  Format  View  Help
Patch posterior probability of presence estimation for
electrofishing using models from Thurow et al 2003

Species group: Bull trout
Number of electrofishing passes:2

Conditional abundance:0.25
Among sample unit coefficient of variation:150.00
Prior probability of patch presence:50.00

        Sample unit detection probablities
 Sample ID Cross sect   Conduct  UndercutModel Abun    TL<200    TL<350
  Buck Cr.      0.952       150          0         1    0.0998    0.1012
 Cold Str.      0.550       100         10         2    0.1043    0.1059
  Fish Cr.      1.015        73          7         5    0.0716    0.0746

Posterior probability of presence for TL<200:0.4281
Posterior probability of presence for TL<350:0.4265
```

```
output2 - Notepad
File  Edit  Format  View  Help
Patch posterior probability of presence estimation for
 user-supplied efficiency.

Beta binomial dispersion parameter:0.2500
Conditional abundance:0.80
Among sample unit coefficient of variation:300.00
Prior probability of patch presence:90.00

        Sample unit detection probablities
   Est eff Model abun          Pr(detect)
       .15         1              0.0669
       .23         2              0.0938
       .61         1              0.1770
       .37         5              0.1313

Posterior probability of presence :0.8447
```

Figure 3.17. An example of CapPost patch-level posterior presence probability estimate output for bull trout 2-pass electrofishing using data in *example 1.csv* (top) and user-supplied efficiency data in *example 2.csv* (bottom). The corresponding example CapPost variable specification menus can be found in Figures 3.15 and 3.16, respectively. Note that the conditional mean abundance is used to calculate the sample unit-specific detection probabilities

4.0 TECHNICAL STUFF

4.1 Capture probability models

CapPost capture efficiency models were fit using combined data from salmonid sampling efficiency research conducted in Idaho 1999 and 2000 (Thurow et al. 2001; Peterson et al. 2004) and Washington 2000 and 2002 (Thurow et al. 2003) using the statistical procedures detailed in Peterson et al. (2004). There were sufficient data for estimating day and night snorkeling efficiency and 1 to 3 pass electrofishing efficiency for bull trout (*Salvelinus confluentus*), cutthroat trout (*Oncorhynchus clarki spp.*), and rainbow trout (*O. mykiss*). There were no detectable differences in sampling efficiency between cutthroat trout and rainbow trout, across sampling gear. Consequently, models were fit using combined data for these species. Separate capture efficiency models were fit using three individual total length size groups: 60-99 mm, 100- 199 mm, and 200-350 mm, and two total length body size ranges: <200 mm and <350 mm. The size groups were based on Peterson et al. (2004) and the length ranges were chosen to represent juvenile salmonids (< 200 mm) and combined juvenile and adult (<350 mm) size ranges. Estimates for fishes > 350 mm TL are not available because these were not encountered during sampling. Results of model fitting with the three size groups and the two body size ranges are shown in Appendices 6.2 and 6.3, respectively.

For each model, predicted capture efficiency was calculated as:

$$\hat{p} = \{1 + \exp(-(\beta_0 + \beta_i x_i ...))\}^{-1} \qquad (1)$$

where $\hat{p}$ is the predicted capture efficiency as a fraction, β_0 is the constant, β_i are the model coefficients in Appendices 6.2 and 6.3, and x_i are the corresponding variable values.

4.2 Detection probability estimation

The detection probability estimate, sample size requirement, and posterior presence probability modules require estimates of detection probabilities. CapPost estimates detection probabilities using two components: (1) a probably distribution function of the number of fish in a sample unit, $P(F_N)$, and (2) the probability of failing to detect any individuals when N are present $P(Co \mid N)$; notation follows Peterson and Bayley (*in press*). Using these two components, CapPost estimates detection probabilities, d, as:

$$d = 1 - \sum_{0} P(Co \mid F_N) \cdot P(F_N). \qquad (2)$$

When users specify a coefficient of variation $\leq 100\%$ or zero for the negative binomial dispersion parameter, CapPost uses a Poisson distribution for $P(F_N)$, otherwise a negative binomial distribution is used. The mean of $P(F_N)$, corresponds to the user-specified mean conditional abundance, the threshold abundance, or site specific abundance. When the negative binomial dispersion parameter is not explicitly specified, it is calculated using the method of moments with the user-specified $P(F_N)$ mean and the coefficient of variation (Poole 1974).

Similar to $P(F_N)$, CapPost uses 2 estimators for $P(Co|N)$, depending on the capture efficiency model or user specifications. A beta-binomial distribution is used to estimate $P(Co|N)$ when the CapPost models are used to estimate salmonid capture efficiency and when the user specifies a beta-binomial dispersion parameter with a user-supplied efficiency (Peterson et al. 2002 and Peterson and Bayley *in press*). A binomial distribution is used to estimate $P(Co|N)$ when a dispersion parameter is not specified with a user-supplied capture efficiency (Peterson and Bayley *in press*).

4.3 Sample size estimation

When no prior probability of presence is specified, sample size requirements are estimated using detection probabilities estimated as outlined above (Section 4.2) and the desired level of 'power' $(1-\beta)$ as:

$$n = ln(\beta)/ln(1-d) \qquad (3)$$

where n is the required number of samples, d is the single sample detection probability, and ln is the natural logarithm (Green and Young 1993).

When a prior probability of presence is specified, CapPost estimates the probability of detection, d', that is required to achieve the user- specified posterior probability following Peterson and Dunham (2003) as:

$$d' = 1 - \frac{P(F_N \mid Co) \cdot P(\sim F_N)}{P(\sim F_N \mid Co) \cdot P(F_N)}, \quad (4)$$

where $P(\sim F_N \mid Co)$ is the complement of the user-specified posterior probability 1- $P(F_N|\underline{Co})$, $P(F_N)$ is the user-specified prior probably and $P(\sim F_N)$ is its complement (i.e., 1- $P[F_N]$). Required sample sizes are estimated by substituting d in equation (3) with d'.

4.7 Posterior presence probabilities

The rationale and derivations of the posterior presence probability estimates are detailed in Bayley and Peterson (2001), Peterson and Dunham (2003), and Peterson and Bayley (*in press*). Site-specific posterior probabilities of presence, P($F|Co$), are estimated using site specific estimates of $P(Co|F_N)$ and $P(F_N)$ following Bayley and Peterson (2001) as:

$$P(F \mid Co) = \frac{\sum_{1} P(Co \mid F_N) \cdot P(F_N)}{\sum_{0} P(Co \mid F_N) \cdot P(F_N)}, \quad (5)$$

where $P(Co|F_N)$ and $P(F_N)$ are defined above (Section 4.2). In contrast, patch/watershed-level posterior probability of presence, $P(F_u \mid Co_u)$, is estimated following Peterson and Dunham (2003) as:

$$P(F_u \mid Co_u) = \frac{\left(\prod_{i=1}^{u}\left(\sum_{1} P(Co_i \mid F_{N_i}) \cdot P(F_{N_i} \mid Oc)\right)\right) \cdot P(Oc)}{\left(\prod_{i=1}^{u}\left(\sum_{1} P(Co_i \mid F_{N_i}) \cdot P(F_{N_i} \mid Oc)\right)\right) \cdot P(Oc) + P(\sim Oc)}, \quad (6)$$

where $P(F_N \mid Oc)$ is the conditional mean abundance PDF specified by the user, $P(Oc)$ is the estimated prior probability of patch occupancy, and $P(\sim Oc)$ is the estimated probability that the patch is unoccupied (i.e., $P(\sim Oc)$ = 1 - $P(Oc)$), and u is the total number of samples collected in the patch.

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6.0 APPENDICES

6.1 Range of sampling conditions during capture efficiency calibrations

Mean, standard deviation (SD), minimum, and maximum of selected habitat characteristics encountered in bull trout capture efficiency evaluation, by sampling method.

Variable	Mean	SD	Minimum	Maximum
Snorkeling, N= 144				
Mean wetted cross sectional area (m^2)	0.856	0.538	0.16	2.55
Stream gradient (%)	3.658	1.885	0.41	11.10
Water temperature (^{0}C)	10.036	2.614	4.00	15.50
Percent undercut banks	9.326	16.833	0.00	93.43
Percent pool habitats	7.165	7.962	0.00	40.40
Wood density (no./m^2)	0.092	0.100	0.00	0.54
Percent gravel	24.218	12.160	5.45	60.80
Percent cobble	30.012	10.046	5.00	56.00
Percent rubble	32.056	18.710	0.67	78.30
Mean visibility (m)	2.669	1.051	1.07	7.80
Electrofishing, N = 145				
Mean wetted cross sectional area (m^2)	0.853	0.537	0.16	2.55
Stream gradient (%)	3.645	1.885	0.41	11.10
Water temperature (^{0}C)	9.286	2.226	3.75	14.25
Conductivity (μohms)	55.248	37.007	10.50	203.00
Percent surface turbulence	27.897	19.506	0.00	90.00
Percent undercut banks	9.293	16.780	0.00	93.43
Percent pool habitats	7.115	7.956	0.00	40.40
Wood density (no./m^2)	0.092	0.100	0.00	0.54
Percent gravel	24.155	12.142	5.45	60.80
Percent cobble	30.110	10.081	5.00	56.00
Percent rubble	32.012	18.652	0.67	78.30

Mean, standard deviation (SD), minimum, and maximum of selected habitat characteristics encountered in Oncorhynchus (cutthroat trout and rainbow trout combined) capture efficiency evaluation, by sampling method.

Variable	Mean	SD	Minimum	Maximum
Snorkeling, N = 82				
Mean wetted cross sectional area (m^2)	0.815	0.458	0.23	2.34
Stream gradient (%)	3.853	1.891	0.41	11.10
Water temperature (^{0}C)	10.248	2.616	4.00	15.50
Percent undercut banks	7.788	14.274	0.00	68.86
Percent pool habitats	6.826	8.259	0.00	40.40
Wood density (no./m^2)	0.081	0.090	0.00	0.54
Percent gravel	21.188	10.829	5.45	54.00
Percent cobble	31.112	10.538	7.00	58.89
Percent rubble	35.885	19.734	0.80	78.30
Mean visibility (m)	2.630	1.134	1.07	7.80
Electrofishing, N= 82				
Mean wetted cross sectional area (m^2)	0.811	0.460	0.23	2.34
Stream gradient (%)	3.829	1.905	0.41	11.10
Water temperature (^{0}C)	9.671	2.347	3.75	14.25
Conductivity (μohms)	53.697	27.000	13.29	147.50
Percent surface turbulence	29.220	18.764	0.00	90.00
Percent undercut banks	7.836	14.256	0.00	68.86
Percent pool habitats	6.782	8.286	0.00	40.40
Wood density (no./m^2)	0.081	0.090	0.00	0.54
Percent gravel	21.212	10.813	5.45	54.00
Percent cobble	31.262	10.638	7.00	58.89
Percent rubble	35.540	19.660	0.80	78.30

6.2 Parameter estimates for size group specific capture efficiency models

Table 3. Parameter estimates, standard errors, and upper and lower 90% confidence limits (CL) from best fitting beta binomial models of bull trout snorkeling efficiencies.

Parameter	Estimate	Standard error	Upper 90% CL	Lower 90% CL
Day snorkeling				
Intercept	-3.984	1.125	-5.829	-2.139
Water temperature	0.094	0.040	0.028	0.160
Mean visibility	1.503	0.706	0.344	2.661
Mean visibility quadratic term	-0.284	0.128	-0.493	-0.074
Percent rubble	-0.020	0.006	-0.030	-0.011
Wood density	-2.128	1.058	-3.863	-0.393
60- 99 mm total length size group	-0.816	0.295	-1.301	-0.332
200- 350 mm total length size group	1.249	0.222	0.885	1.613
Shape parameter	0.187	0.021	0.152	0.222
Night snorkeling				
Intercept	-1.371	0.335	-1.920	-0.822
Water temperature	0.066	0.029	0.017	0.114
Percent pool habitats	0.014	0.008	0.001	0.026
60- 99 mm total length size group	-1.224	0.216	-1.579	-0.870
200- 350 mm total length size group	0.925	0.170	0.646	1.205
Shape parameter	0.110	0.011		

Parameter estimates, standard errors, and upper and lower 90% confidence limits (CL) from best fitting beta binomial models of bull trout electrofishing efficiencies.

	Estimate	Standard error	Upper 90% CL	Lower 90% CL
One pass electrofishing				
Intercept	-0.516	0.176	-0.804	-0.227
Mean wetted cross sectional area	-1.109	0.171	-1.389	-0.828
Percent undercut banks	-0.010	0.003	-0.015	-0.005
Conductivity	0.005	0.001	0.003	0.007
60- 99 mm total length size group	-0.803	0.166	-1.075	-0.532
200- 350 mm total length size group	0.533	0.155	0.278	0.787
Shape parameter	0.049	0.005		
Two pass electrofishing				
Intercept	0.134	0.175	-0.154	0.421
Mean wetted cross sectional area	-1.117	0.161	-1.381	-0.853
Percent undercut banks	-0.011	0.003	-0.016	-0.006
Conductivity	0.005	0.001	0.003	0.007
60- 99 mm total length size group	-0.839	0.155	-1.093	-0.585
200- 350 mm total length size group	0.513	0.161	0.249	0.777
Shape parameter	0.077	0.007		
Three pass electrofishing				
Intercept	0.360	0.188	0.051	0.669
Mean wetted cross sectional area	-0.912	0.155	-1.166	-0.657
Percent undercut banks	-0.013	0.003	-0.018	-0.008
Conductivity	0.004	0.001	0.002	0.006
60- 99 mm total length size group	-0.876	0.155	-1.130	-0.622
200- 350 mm total length size group	0.466	0.170	0.187	0.745
Shape parameter	0.097	0.009		

Parameter estimates, standard errors, and upper and lower 90% confidence limits (CL) from best fitting beta binomial models of Oncorhynchus (cutthroat trout and rainbow trout combined) snorkeling efficiencies.

Parameter	Estimate	Standard error	Upper 90% CL	Lower 90% CL
Day snorkeling				
Intercept	-1.636	0.287	-2.106	-1.165
Mean wetted cross sectional area	-0.738	0.275	-1.189	-0.286
60- 99 mm total length size group	-1.743	0.426	-2.441	-1.045
200- 350 mm total length size group	0.680	0.280	0.220	1.139
Shape parameter	0.069	0.011		
Night snorkeling				
Intercept	-0.489	0.266	-0.925	-0.052
Percent pool habitats	0.025	0.013	0.003	0.046
Percent rubble	-0.009	0.005	-0.016	-0.001
60- 99 mm total length size group	-1.587	0.246	-1.990	-1.184
200- 350 mm total length size group	0.406	0.253	-0.009	0.820
Shape parameter	0.081	0.011		

Parameter estimates, standard errors, and upper and lower 90% confidence limits (CL) from best fitting beta binomial models of Oncorhynchus (cutthroat trout and rainbow trout combined) electrofishing efficiencies.

	Estimate	Standard error	Upper 90% CL	Lower 90% CL
One pass electrofishing				
Intercept	-0.662	0.132	-0.878	-0.446
Mean wetted cross sectional area	-0.179	0.154	-0.432	0.074
60- 99 mm total length size group	-0.846	0.179	-1.139	-0.553
200- 350 mm total length size group	0.132	0.220	-0.229	0.493
Shape parameter	0.031	0.005		
Two electrofishing				
Intercept	-0.372	0.359	-0.961	0.216
Percent cobble	-0.010	0.007	-0.022	0.002
Water temperature	0.054	0.031	0.003	0.106
60- 99 mm total length size group	-0.898	0.168	-1.173	-0.623
200- 350 mm total length size group	0.203	0.223	-0.163	0.569
Shape parameter	0.061	0.008		
Three pass electrofishing				
Intercept	-0.025	0.392	-0.668	0.617
Percent pool habitats	-0.019	0.011	-0.038	-0.001
Percent cobble	-0.012	0.007	-0.024	0.000
Water temperature	0.058	0.033	0.005	0.112
60- 99 mm total length size group	-0.936	0.162	-1.203	-0.670
200- 350 mm total length size group	0.155	0.230	-0.223	0.532
Shape parameter	0.070	0.009		

6.3 Parameter estimates for size range capture efficiency models

Parameter estimates, standard errors, and upper and lower 90% confidence limits (CL) from best fitting beta binomial models of bull trout snorkeling efficiencies for two total length (TL) size classes.

	Estimate	Standard error	Upper 90% CL	Lower 90% CL
Day snorkeling, < 200 mm TL				
Intercept	-4.087	1.733	-5.528	0.155
Water temperature	0.040	0.056	-0.052	0.132
Wood density	-2.453	1.583	-5.049	0.143
Percent rubble	-0.024	0.008	-0.037	-0.012
Mean visibility	1.511	1.327	-0.664	3.687
Mean visibility quadratic term	-0.242	0.236	-0.629	0.145
Shape parameter	0.159	0.019		
Day snorkeling, < 350 mm TL				
Intercept	-3.455	1.447	-5.029	-0.282
Water temperature	0.082	0.047	0.004	0.159
Wood density	-1.742	1.442	-4.108	0.623
Percent rubble	-0.015	0.006	-0.025	-0.004
Mean visibility	1.292	1.179	-0.642	3.225
Mean visibility quadratic term	-0.220	0.214	-0.570	0.130
Shape parameter	0.247	0.033		
Night snorkeling, < 200 mm TL				
Intercept	-1.459	0.253	-1.873	-1.044
Water temperature	0.031	0.018	0.001	0.060
Percent pool habitats	0.009	0.006	-0.001	0.019
Shape parameter	0.079	0.023		
Night snorkeling, < 350 mm TL				
Intercept	-1.499	0.362	-2.093	-0.904
Water temperature	0.071	0.033	0.016	0.125
Percent pool habitats	0.021	0.009	0.007	0.035
Shape parameter	0.165	0.056		

Parameter estimates, standard errors, and upper and lower 90% confidence limits (CL) from best fitting beta binomial models of bull trout electrofishing (EF) efficiencies for two total length (TL) size classes.

	Estimate	Standard error	Upper 90% CL	Lower 90% CL
One pass EF, < 200 mm TL				
Intercept	-0.556	0.203	-0.889	-0.222
Percent undercut banks	-0.015	0.004	-0.022	-0.008
Conductivity	0.005	0.001	0.003	0.008
Mean wetted cross sectional area	-1.203	0.204	-1.538	-0.868
Shape parameter	0.049	0.017		
One pass EF, < 350 mm TL				
Intercept	-0.675	0.206	-1.013	-0.338
Percent undercut banks	-0.007	0.003	-0.012	-0.002
Conductivity	0.005	0.001	0.003	0.007
Mean wetted cross sectional area	-1.034	0.193	-1.351	-0.718
Shape parameter	0.053	0.008		
Two pass EF, < 200 mm TL				
Intercept	0.078	0.226	-0.292	0.448
Percent undercut banks	-0.015	0.004	-0.021	-0.008
Conductivity	0.005	0.002	0.002	0.007
Mean wetted cross sectional area	-1.156	0.198	-1.481	-0.831
Shape parameter	0.051	0.018		
Two pass EF, < 350 mm TL				
Intercept	-0.034	0.219	-0.394	0.325
Percent undercut banks	-0.009	0.003	-0.014	-0.003
Conductivity	0.005	0.001	0.003	0.007
Mean wetted cross sectional area	-1.039	0.189	-1.349	-0.729
Shape parameter	0.061	0.015		
Three pass EF, < 200 mm TL				
Intercept	0.283	0.252	-0.130	0.695
Percent undercut banks	-0.017	0.004	-0.024	-0.010
Conductivity	0.004	0.002	0.002	0.007
Mean wetted cross sectional area	-0.923	0.194	-1.242	-0.605
Shape parameter	0.080	0.035		
Three pass EF, < 350 mm TL				
Intercept	0.198	0.245	-0.204	0.599
Percent undercut banks	-0.011	0.004	-0.017	-0.005
Conductivity	0.004	0.002	0.002	0.007
Mean wetted cross sectional area	-0.837	0.187	-1.143	-0.531
Shape parameter	0.068	0.010		

Parameter estimates, standard errors, and upper and lower 90% confidence limits (CL) from best fitting beta binomial models of Oncorhynchus (cutthroat trout and rainbow trout combined) snorkeling efficiencies for two total length (TL) size classes.

	Estimate	Standard error	Upper 90% CL	Lower 90% CL
Day snorkeling, < 200 mm TL				
Intercept	-2.361	0.344	-2.926	-1.796
Mean wetted cross sectional area	-0.348	0.186	-0.653	-0.044
Shape parameter	0.084	0.014		
Day snorkeling, < 350 mm TL				
Intercept	-2.199	0.372	-2.809	-1.589
Mean wetted cross sectional area	-0.403	0.244	-0.803	-0.003
Shape parameter	0.076	0.012		
Night snorkeling, < 200 mm TL				
Intercept	-1.047	0.276	-1.499	-0.595
Percent pool habitats	0.033	0.018	0.004	0.061
Percent rubble	-0.008	0.005	-0.015	0.000
Shape parameter	0.094	0.013		
Night snorkeling, < 350 mm TL				
Intercept	-0.766	0.330	-1.308	-0.225
Percent pool habitats	0.023	0.020	-0.009	0.055
Percent rubble	-0.010	0.007	-0.021	0.001
Shape parameter	0.087	0.012		

Parameter estimates, standard errors, and upper and lower 90% confidence limits (CL) from best fitting beta binomial models of Oncorhynchus (cutthroat trout and rainbow trout combined) electrofishing (EF) efficiencies for two total length (TL) size classes.

	Estimate	Standard error	Upper 90% CL	Lower 90% CL
One pass EF, < 200 mm TL				
Intercept	-0.906	0.148	-1.148	-0.664
Mean wetted cross sectional area	-0.047	0.029	-0.094	0.000
Shape parameter	0.060	0.010		
One pass EF, < 350 mm TL				
Intercept	-0.860	0.154	-1.113	-0.608
Mean wetted cross sectional area	-0.059	0.015	-0.083	-0.035
Shape parameter	0.033	0.005		
Two pass EF, < 200 mm TL				
Intercept	-0.738	0.542	-1.627	0.150
Percent cobble	-0.010	0.007	-0.021	0.000
Water temperature	0.063	0.036	0.004	0.122
Shape parameter	0.068	0.009		
Two pass EF, < 350 mm TL				
Intercept	-0.442	0.248	-0.849	-0.036
Percent cobble	-0.013	0.006	-0.022	-0.004
Water temperature	0.051	0.029	0.004	0.098
Shape parameter	0.064	0.008		
Three pass EF, < 200 mm TL				
Intercept	-0.264	0.257	-0.686	0.158
Percent pool habitats	-0.011	0.007	-0.022	0.000
Percent cobble	-0.014	0.008	-0.026	-0.001
Water temperature	0.060	0.031	0.009	0.112
Shape parameter	0.083	0.010		
Three pass EF, < 350 mm TL				
Intercept	-0.114	0.144	-0.350	0.122
Percent pool habitats	-0.011	0.006	-0.021	-0.001
Percent cobble	-0.016	0.009	-0.030	-0.001
Water temperature	0.058	0.034	0.002	0.113
Shape parameter	0.076	0.009		